Concepts For Ocean Worlds Life Detection Technology

Precise Landing on Titan

Completed Technology Project (2016 - 2018)

Project Introduction

Saturn's moon Titan is the richest laboratory in the solar system for studying prebiotic chemistry, which makes studying its chemistry from the atmosphere to the surface one of the most important objectives in planetary science. Studying Titan's organic chemistry requires landing to sample and analyze fluids, dissolved species, and sediments from Titan's seas, lakes, tidal pools, or shorelines. Landing dispersions with existing technology are hundreds of kilometers wide, precluding landing in any liquid body except the large seas at high northern latitudes. Low to medium cost missions require direct to Earth (DTE) communication; seasons on Titan now prevent such missions to northern seas for landings before the late 2030s. With these large landing dispersions, access to shorelines or other smaller features on Titan, which may present liquid-solid interfaces or more dynamic environments conducive to more chemical evolution, is only conceivable by relying on wind drift after landing on large seas. Therefore, there is a critical need for more precise landing capability to explore the unique potential for prebiotic chemistry on Titan's surface. We propose technology development to substantially reduce Titan lander delivery error. By far the greatest contribution to this error in past Titan mission designs has been long parachute descent phases (~ 2.5 hours) from high altitudes (~ 150 km) in high winds with large wind uncertainties; therefore, addressing error during parachute descent is the key to enabling precision landing. Lowest delivery error would be achieved with a multi-stage parachute system, with an unguided drogue parachute that descends rapidly through altitudes with high winds, followed by a guided parafoil with a high glide ratio that flies out position error at lower altitudes. Parafoil deployment at altitudes up to 40 km, where proven descent camera technology could see the surface to enable position estimation, could reduce delivery error by 100 km or more. The main risk areas in this concept are uncertainty in the precision of descent navigation and in parafoil guidance and control (G&C) performance. The only possible source of adequate position knowledge is onboard terrain-relative navigation (TRN), using a camera to recognize and track features of Titan's surface during descent. TRN for precision landing on Mars is now at TRL 6 and is expected to be at TRL 9 by 2021 as part of the 2020 Mars rover mission. Leveraging that development has potential to make TRN available for Titan at relatively low cost in a relatively short timeframe; however, factors unique to Titan require changes to the design of the TRN system. Parafoil aerodynamic performance has not been characterized yet for the dense Titan atmosphere and parafoil G&C algorithms must be adapted to unique characteristics of Titan missions. We propose to raise the TRL of Titan precision landing from 2 to 4 by developing key elements of Titan TRN image matching and parafoil G&C algorithms, developing models for TRN navigation error and for parafoil G&C error, developing a simulation of end-to-end EDL performance, and using the simulation to estimate and optimize expected landing dispersion, with the goal of showing feasibility of reducing delivery error by at least 100 km compared to Huygens-like descent. Success in that endeavor would enable using this capability for Titan missions as early as

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Organizational Responsibility

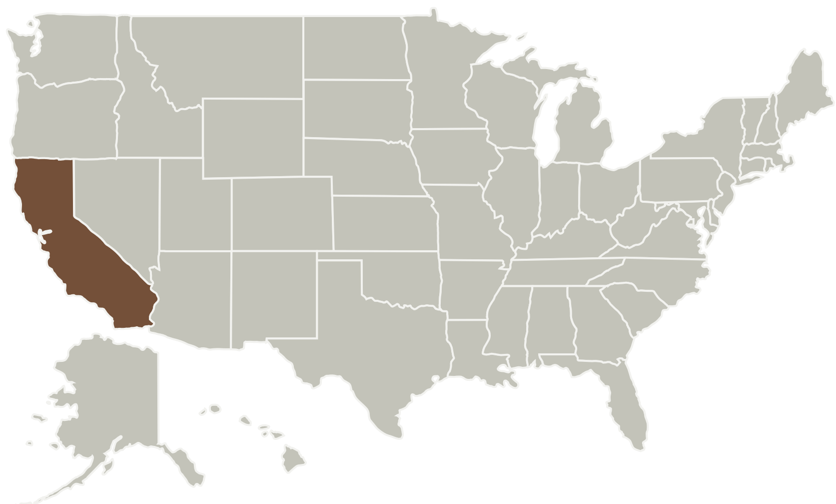
Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Concepts for Ocean Worlds Life Detection Technology launch opportunities in the late 2020s. To achieve Titan precision landing in this timeframe requires starting this technology development now.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
California Institute of Technology(CalTech)	Supporting Organization	Academia	Pasadena, California

Primary U.S. Work Locations
California

Project Management

Program Director:

Carolyn R Mercer

Program Manager:

Carolyn R Mercer

Principal Investigator:

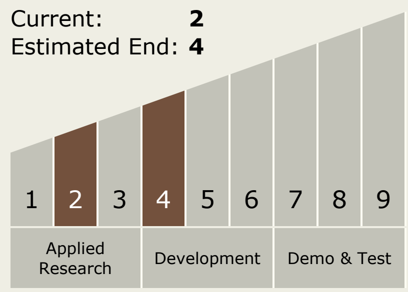
Larry Matthies

Co-Investigators:

Bruno M Quadrelli
Nikolas Trawny
Karen R Piggee
Michael J Malaska
Evgeniy B Sklyanskiy
Robert J Sinclair
Aron A Wolf

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **4**



Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  └ TX09.2 Descent

Continued on following page.

Technology Areas *(cont.)*

└ TX09.2.1 Aerodynamic Decelerators

Target Destination

Others Inside the Solar System